SECTION 8

ECONOMIC EVALUATION

The economic evaluation of alternative storm and combined sewer
designs with respect to the use of catchbasins or inlets is
described and illustrated in this section. Economic criteria are
presented, along with basic cost information, an analysis of
alternatives, and a brief summary discussion.

ECONOMIC CRITERIA

To properly assess the economic feasibility of alternative storm
sewer installations, it is necessary to prepare detailed cost
estimates. Before such estimates can be prepared, however,
economic criteria must be selected to ensure that equivalent
costs are compared. For example, a true evaluation of
alternatives can be based on present worth or annual cost. In
general, annual cost comparisons are preferred because the
significance of the cost components is more easily understood.
For this reason, annual cost comparisons are used in this report.

Components of annual costs include operation, maintenance,
supervision, depreciation, and interest on borrowed capital.
Annual interest and depreciation, commonly referred to as "fixed
costs," are computed using the capital recovery method [107].
The recommended recovery period (also referred to as useful life)
for storm sewers will vary from 20 to 40 years. Often, short
return periods are used when future plans are uncertain,
especially with regard to regionalization. The current (November
1976) interest rate charged on borrowed money varies from 7 to
10 percent.

Because costs are changing so rapidly, both nationally and
locally, it is extremely important that any cost evaluation be
referenced to some index. One of the most common is the
Engineering News-Record Construction Cost (ENRCC) index. Other
important indexes include the EPA Sewer Cost and Treatment Plant
indexes. When possible, index values should also be adjusted to
reflect local costs, which may be higher or lower than the
national index. An ENRCC index of 2000 is used in this report.
The following formula can be used to adjust the reported costs to
another index value:

$$\text{adjusted cost} = (\text{reported cost}) \left(\frac{\text{value of index}}{2000}\right)$$

COST DATA AND INFORMATION

To properly evaluate alternative plans involving the use of catchbasins or inlets, data must be available on catchbasin and inlet construction costs, cleaning costs for catchbasins and inlets, and sewer cleaning costs.

Catchbasin and Inlet Costs

After a drainage system has been designed, inlet facilities can be constructed using either a standard inlet or a catchbasin without affecting the design, since both devices have practically the same maximum hydraulic capacity. Typical cost data for catchbasins and inlets are presented in Table 28. The reported costs will vary, depending on the size of the catchbasin or standard inlet used by a particular city, but it can be assumed that the construction cost of a typical catchbasin will be about 20 to 40 percent more than the cost of a standard inlet. Catchbasin costs are shown in Figure 35 as a function of retained storage capacity.

TABLE 28. COST DATA FOR
CATCHBASINS AND INLETS

	Catchbasins		Inlets	
	Range	Avg	Range	Avg
Total installed cost, $[a]	400-1,000	800	300-800	600

a. Based on an ENRCC index of 2000.

Catchbasin and Inlet Cleaning Costs

Catchbasin cleaning, when done adequately, is an expensive aspect of catchbasin use. The operation and maintenance costs of a catchbasin consist of (1) the catchbasin cleaning and debris disposal costs, (2) maintenance costs of those items of the catchbasin not found in a standard inlet, such as the trap and sump, and (3) the operation and maintenance costs of the catchbasin cleaning equipment prorated if used for other purposes, such as leaf removal from gutters. Catchbasin cleaning costs will vary, depending on the method used, the required cleaning frequency, the amount of debris removed, and debris disposal costs.

Typical costs for cleaning catchbasins by hand, with an eductor, and by vacuum, are reported in Table 29 both for those regions
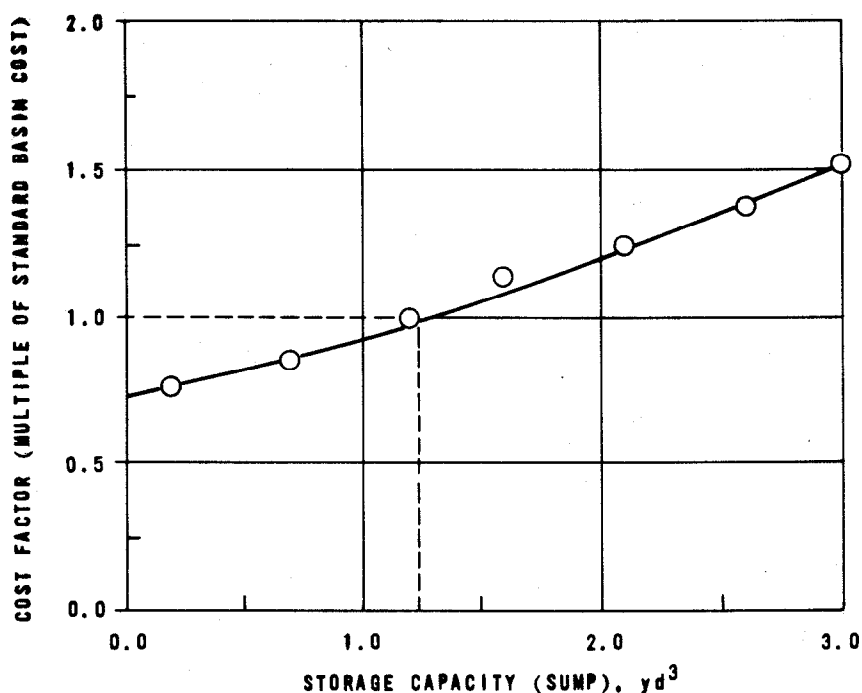
Figure 35. Catchbasin cost versus storage capacity

TABLE 29.   CATCHBASIN CLEANING COSTS[a,b]

Statistical measure[c]	Manual cleaning			Eductor cleaning			Vacuum cleaning		
	$/catch-basin	$/m^3	($/yd^3)	$/catch-basin	$/m^3	($/yd^3)	$/catch-basin	$/m^3	($/yd^3)
Regions with heavy winter snowfall									
Sample size	17	10		5	6		26	14	
Geometric mean, M_g	10.53	9.08	(6.94)	3.23	3.01	(2.30)	4.94	9.86	(7.54)
Standard deviation, σ_g	4.53	10.10	(7.72)	3.38	17.76	(13.58)	2.97	2.20	(1.68)
National									
Sample size	51	37		10	10		51	37	
Geometric mean, M_g	7.66	18.86	(14.42)	5.92	5.35	(4.09)	7.99	11.24	(8.59)
Standard deviation, σ_g	3.04	11.18	(8.55)	3.30	13.18	(10.08)	3.05	5.95	(4.55)

a.   Based on an ENRCC index of 2000.

b.   Data from APWA survey.

c.   See Appendix B.

(using breakdowns of survey data by state) with heavy winter snowfall and all of the regions considered together. The cost comparisons between cleaning methods appear reasonable; however, the unit costs as a group appear low and should be verified against local experience. In the case of hand cleaning,

cleaning costs would be expected to be more expensive in regions with heavy snowfall because of exposure. Cleaning costs with eductor and vacuum systems in regions with heavy snowfall should be lower because there are more catchbasins per unit area, and the basins are usually cleaned more frequently. Geographic location as related to the pollution load is also a factor.

Although there is little information or cost data available, inlet cleaning costs must be considered in any analysis of alternatives. On the basis of limited data, it appears that cleaning costs for inlets are about $3.00 per inlet using a vacuum system. The costs will vary with location and the design of the inlet.

Sewer Cleaning Costs

Cleaning costs for sewers will vary with the size of the sewer and amount of material to be removed. Representative sewer cleaning costs based on the sewer size are reported in Table 30. In view of the magnitude of the costs involved in cleaning sewers of any type, accurate cost data must be obtained for local conditions before preparing an economic evaluation of alternatives where sewer cleaning costs will be a central issue.

TABLE 30.   REPRESENTATIVE
SEWER CLEANING COSTS[a]

Sewer size and type	Cost	
	$/cm diam per lin m	($/in. diam per lin ft)
Diameter ≤122 cm (≤48 in.)[b]		
Storm	0.095	(0.075)
Combined	0.195	(0.15)
Diameter >122 cm (>48 in.)		
Storm	0.13	(0.10)
Combined[c]	0.26	(0.20)

a. Based on an ENRCC index of 2000.

b. Range $0.03 to $0.19 in. diam per lin ft [111].

c. In Boston, 13,000 ft of 60 in. diam combined sewer was cleaned for a total cost of $11.50 per foot of sewer [112].

ECONOMIC ANALYSIS OF ALTERNATIVES

Because of the expense involved, sewer cleaning frequency is a prime consideration in the installation of a catchbasin.

Ultimately, the cost differential between the installation of catchbasins and the installation of inlets can be defined as:

$$\Delta \text{cost} = \Delta \text{ installation cost} + \Delta \text{ sewer cleaning cost} + \Delta \text{ catchbasin/inlet cleaning cost} + \Delta \text{ pollution costs associated with use of catchbasins}$$

The pollution cost term is composed of (1) cost savings associated with grit or pollution load savings attributable to the catchbasin cleaning program and (2) costs associated with any pollution load attributable to the use of catchbasins. These two costs are difficult to evaluate in most systems but may be measurable in large systems. For practical purposes, the decision on whether or not to install a system with catchbasins or inlets can be made by comparing (1) the annual costs for the initial installation of catchbasins or inlets, (2) the yearly cleaning costs, and (3) the equivalent annual costs for sewer cleaning for each system. The actual computations involved in the preparation of an economic evaluation of alternatives are illustrated in the following examples. The first two examples deal with the conversion of catchbasins to inlets in an existing system. The third example deals with the question of whether to install catchbasins or inlets in a new installation. The fourth example illustrates the choice between the purchase of additional equipment and investing in structural improvements.

EXAMPLE PROBLEM 4:   ECONOMIC EVALUATION OF CONVERTING CATCHBASINS TO INLETS IN AN EXISTING STORM SEWER SYSTEM

Prepare an annual cost comparison between the continued operation of a storm sewer with catchbasins and the same system if the catchbasins are converted to inlets for return periods of 10, 20, 30, and 40 years.

Specified Conditions

    1.   Total number of catchbasins in storm sewer system = 140.
    2.   Storm sewer sizes, lengths, and volumes:

Diam, in.	Length, ft	Volume, ft³
12	10,000	7,850
18	5,000	8,840
24	4,000	12,570
36	4,000	28,270

    3.   Storm sewers with catchbasins are cleaned once every 10 years.
    4.   Existing catchbasins are well designed, cleaned twice every year, and achieve a 50 percent capture of the entering material.

Discussion

Separate storm sewer systems are traditionally designed to provide localized flood relief at minimum cost. This frequently results in mixed systems of natural channel, improved open channel, and enclosed conduit subsystems in various combinations. As a result, street drainage, which may or may not be routed through catchbasins, constitutes only a portion of the solids entry to the system. In this example it is assumed that the solids deposited in the enclosed conduit subsystem become cost effective to remove when the total volume of the enclosed conduits is reduced 10 percent [57,530 ft³ x 0.10 = 5,753 ft³].

In the specified case of storm sewers with catchbasins, this accumulation is reached every 10 years on the average, representing an annual accumulation of of 575 ft^3 per year, even though the storm sewers have been constructed with "self-cleaning" velocities.

Under the modified conditions, catchbasins replaced with inlets, the accumulation rate will be increased in proportion to the additional solids entering but not carried through the system. Assuming the catchbasins each had a sump volume of 1.7 yd^3 and were cleaned on the average when they were 40 percent full, the total sediment removed per year per basin was 36.7 ft^3 [1.7 yd^3 x 27 ft^3/yd^3 x 2 times per year x .40 full = 36.7 ft^3] and for all catchbasins was 5,141 ft^3 per year [140 basins x 36.7 ft^3 = 5,141 ft^3]. Because of the "self cleaning" velocities most, say 90 percent, of this material would pass through the storm sewer system. The remaining 10 percent, however, represents an additional annual accumulation in the storm sewers of 514 ft^3 per year; thus almost doubling the accumulation rate from 575 ft^3 per year to 1,089 ft^3 per year and shortening the time between sewer cleanings from 10 years to 5 years (see Assumption 6 below).

Assumptions

1. Catchbasins and sewers have just been cleaned.
2. The cost of cleaning each catchbasin using a vacuum system = $8 per cleaning (see Table 29).
3. Sewer cleaning costs are as specified in Table 30.
4. The cost of converting a catchbasin to an inlet = $200.
5. Each inlet will have to be cleaned once every 2 years at a cost of $3 per inlet.
6. If the catchbasins are converted inlets, it is anticipated that the sewers will have to be cleaned once every 5 years.
7. Interest rate = 8%.
8. Inflation rate for sewer cleaning costs = 4%.
9. Catchbasin and inlet cleaning costs will increase by $0.50 and $0.15 each year, respectively. These cost increases are consistent with improvements in equipment which tend to decrease costs.

Solution

1. Determine the sewer cleaning costs at today's prices.

Pipe diam, in.	Length, ft	Cost, $ Per lin ft	Cost, $ Total
12	10,000	0.90	9,000
18	5,000	1.35	6,750
24	4,000	1.80	7,200
36	4,000	2.70	10,800
Total for system			33,750

2. Determine the future sewer cleaning costs taking into account inflation and converting those costs to present worth.

Time, yr	Factor[a]	Cost, $	Present worth Factor[b]	Present worth Cost, $
0	1.000	33,750	1.0000	33,750
5	1.217	41,074	0.6806	27,955
10	1.480	49,950	0.4632	23,137
15	1.801	60,784	0.3152	19,159
20	2.191	73,946	0.2145	15,861
25	2.666	89,977	0.1460	13,137
30	3.243	109,451	0.0994	10,879
35	3,946	133,177	0.0676	9,003
40	4.801	162,034	0.0460	7,454

a. Single payment compound amount factor at 4% for the period shown in years.

b. Single payment present worth factor at 8% for the period shown in years.

3. Determine the present worth of the sewer cleaning costs for each alternative plan for the various return periods, and convert those costs to a uniform annual cost for those periods.

Period, yr	Alternative 1[a] Present worth, $	Factor[c]	Annual cost, $	Alternative 2[b] Present worth, $	Factor[c]	Annual cost, $
10	23,137	0.14903	3,448	51,092	0.14903	7,614
20	38,998[d]	0.10185	3,972	86,112	0.10185	8,770
30	49,877	0.08883	4,431	110,128	0.08883	9,783
40	57,331	0.08386	4,808	126,585	0.08386	10,615

a. Retain catchbasins.

b. Convert catchbasins to inlets.

c. Capital recovery factor at 8% for the period shown in years.

d. From Step 2 ($38,998 = $23,137 + $15,861).

4. Determine the initial cost of converting the catchbasins to inlets, and convert this cost to a uniform annual cost.
Conversion cost = 140 x $200/conversion = $28,000.
Convert the initial cost to annual cost.

Period, yr	Factor	Annual cost, $
10	0.14903	4,173
20	0.10185	2,852
30	0.08883	2,487
40	0.08386	2,348

5. Determine the annual cost of cleaning the catchbasins for the various return periods.

Period, yr	Base cost, $	Gradient factor[a]	Gradient cost, $	Annual cost, $
10	2,240	3.87	542[b]	2,782
20	2,240	7.04	986	3,226
30	2,240	9.19	1,287	3,527
40	2,240	10.57	1,480	3,720

a. Accounts for yearly incremental increase in cost at i = 8% [107 pp 50-52].

b. 140 basins x $0.50 annual cost increase x 3.87 x 2 cleanings/yr.

6. Determine the annual cost of cleaning the inlets for the various return periods.

Period, yr	Base cost, $	Gradient factor	Gradient cost, $	Annual cost, $
10	210	3.87	41	251
20	210	7.04.	74	284
30	210	9.19	96	306
40	210	10.57	111	321

7. Prepare a summary of the annual costs for each alternative.

Alternative	Return period, yr	Annual cost, $ Catchbasin conversion	Sewer cleaning	Catchbasin cleaning	Inlet cleaning	Total
1 - Retain catchbasins	10	--	3,449	2,782	--	6,230
	20	--	3,972	3,226	--	7,198
	30	--	4,431	3,527	--	7,958
	40	--	4,808	3,720	--	8,528
2 - Convert catchbasins to inlets	10	4,173	7,614	--	251	12,038
	20	2,852	8,770	--	284	11,906
	30	2,487	9,783	--	306	12,576
	40	2,348	10,615	--	321	13,284

Comment

From the computational summary presented in Step 7 of the solution, it can be concluded that the cost and required frequency of cleaning the existing sewers is the dominating economic consideration with respect to conversion of catchbasins to inlets. For example, if the sewer cleaning frequency were to remain the same after conversion (i.e., sewer cleaning costs would be the same in each alternative), the economic advantage would switch to Alternative 2 by the 20th year. [$2,852 conversion + $3,972 sewer cleaning + $284 inlet cleaning = $7,108 which is less than $7,198].

EXAMPLE PROBLEM 5: RECONSIDERATION OF PROBLEM 4 WHERE SEWER CLEANING CONCERNS ARE LIMITED TO A SMALL PORTION OF THE SYSTEM.

Repeat the annual cost comparison of Problem 4 assuming that 90 percent of the specified storm sewer system is known to be free of solids sedimentation problems.

Specified Conditions

1. Same as Problem 4, except that trouble spots with respect to solids deposition are known and limited to 10 percent of the pipe network.

Assumptions

1. The trouble spots are contiguous and cleaning unit costs remain the same.
2. The storm sewer sizes and lengths requiring cleaning remain in the same proportions as in Problem 4.

Solution

1. Repeat Step 7 of Problem 4, except reduce the sewer cleaning costs to 10 percent of their previous value.

Alternative	Return period, yr	Annual cost, $				
		Catchbasin conversion	Sewer cleaning	Catch-basin cleaning	Inlet cleaning	Total
1 - Retain catchbasins	10	--	345	2,782	--	3,127
	20	--	397	3,226	--	3,623
	30	--	443	3,527	--	3,970
	40	--	481	3,720	--	4,201
2 - Convert catchbasins to inlets	10	4,173	761	--	251	5,185
	20	2,852	877	--	284	4,013
	30	2,487	978	--	306	3,771
	40	2,348	1,061	--	321	3,730

Comment

Knowledge and understanding of the operational characteristics of the specific system under study is an essential input to the analysis for proper decision-making.

EXAMPLE PROBLEM 6: ECONOMIC EVALUATION OF INSTALLING CATCHBASINS OR INLETS IN A NEW DEVELOPMENT

Prepare an economic comparison based on annual cost of the installation of catchbasins and inlets in a proposed new development in which separate storm sewers are to be used. Omit the storm sewer construction cost, as it will be the same for both systems. Also, determine the sewer cleaning frequency at which the annual costs for the two alternatives are essentially the same.

Specified Conditions

1. Development area = 520 acres.
2. Separate storm sewers are to be installed.
3. Return period for project = 36 years.
4. Interest rate = 8%.
5. Neglect inflation costs in economic analysis.

Assumptions

1. Catchbasin density = 0.46/acre.
2. Cost of cleaning each catchbasin using a vacuum system = $8 (see Table 29).
3. Cost of cleaning each inlet = $3.
4. Sewer cleaning costs as specified in Table 30.
5. Catchbasins will be cleaned twice per year.
6. Inlets will be cleaned once per year.
7. Cleaning of storm sewers with catchbasins will occur once every 18 years.
8. Prepare computations assuming that the storm sewers with inlets will have to be cleaned every 6, 9, 12, 15, and 18 years (see discussion under Example Problem 4).

Solution

1. Total number of catchbasins required = 240 (520 acres x 0.46 catchbasins/acre).
2. Using four 130-acre units, a typical layout for the interceptor storm sewers is presented below:
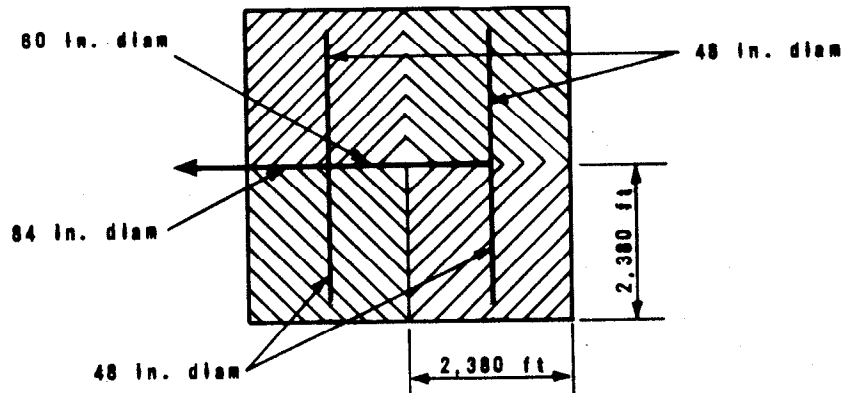
3. The corresponding storm sewer pipe size distribution for each 130-acre parcel might be as follows:

Pipe diam, in.	Length, ft
10	530
15	4,450
18	880
24	3,100
30	1,030
36	1,200
48	1,900

The exact pipe size distribution will vary with each location.

4. Compute the cost of cleaning the storm sewers.

Pipe diam, in.	Total length, ft	Cost, $ Per ft	Cost, $ Total
10	2,120	0.75	1,590
15	17,800	1.12	19,936
18	3,520	1.35	4,752
24	12,400	1.80	22,320
30	4,120	2.25	9,270
36	4,800	2.70	12,960
48	7,600	3.60	27,360
60	2,380	4.50	10,710
84	1,190	6.30	7,497
Total cost			116,395

5. Compute the present worth of future cleaning costs.

Time, yr	Factor[a]	Cost, $
6	0.6302	73,352
9	0.5002	58,221
12	0.3971	46,220
15	0.3152	36,688
18	0.2502	29,122
24	0.1577	18,355
27	0.1252	14,573
30	0.0994	11,570
36	0.0626	7,286

a. Single payment present worth factor at 8% for the period shown in years.

6. Determine the total present worth of future cleaning costs and convert them to annual costs.

Alternative	Cleaning interval, yr	Total present worth, $	Factor[a]	Annual cost, $
Storm sewers with catchbasins	18	36,408[b]	.08535	3,107
Storm sewers with inlets	6	185,905	.08535	15,867
	9	109,202	.08535	9,320
	12	71,861	.08535	6,133
	15	48,258	.08535	4,119
	18	36,408	.08535	3,107

a. Capital recovery factor at 8% for 3-year period.
b. Sum of present worths (Step 5) for 18th and 36th year.

7. Determine the annual cost of installing catchbasins.

   $800/catchbasin x 240 catchbasins x 0.08535 = $16,387/yr

8. Determine the annual cost of installing inlets.

   $600/inlet x 240 inlets x 0.08535 = $12,290/yr

9. Determine the annual cleaning cost for catchbasins.

   240 catchbasins x 2 cleanings/yr x $8/catchbasin = $3,480/yr

10. Determine the annual cleaning cost for inlets.

   240 inlets x 1 cleaning/yr x $3/inlet = $720/yr

11. Prepare a summary of annual costs excluding storm sewer construction costs, which will be the same for both systems.

Alternative	Cleaning interval, yr	Annual cost, $			
		Construction	Catchbasin or inlet cleaning	Sewer cleaning	Total
Storm sewers with catchbasins	18	16,387	3,840	3,107	23,334
Storm sewers with inlets	6	12,290	720	15,867	28,877
	9	12,290	720	9,320	22,330
	12	12,290	720	6,133	19,143
	15	12,290	720	4,119	17,129
	18	12,290	720	3,107	16,117

12. Determine the sewer cleaning frequency at which the costs for the two systems are essentially the same. Based on the cost information presented in Step 11, the annual cost for the two systems will be about the same when the sewer cleaning frequency for the system with inlets is approximately equal to 8.5 years.

EXAMPLE PROBLEM 7:   ECONOMIC COMPARISON BETWEEN STRUCTURAL AND NONSTRUCTURAL ALTERNATIVES

This example illustrates yet another option to be considered by city administrators. Should a proposed capital investment be placed into equipment that will improve the effectiveness of maintenance of the existing system, or should a corresponding investment be used for structural modifications that will reduce the need for maintenance?

A community has 5,000 catchbasins that are presently cleaned once per year. This cleaning frequency has proven to be inadequate and plans have been proposed either to:

1. Double the cleaning frequency by the purchase and operation of a new mechanical cleaner, or
2. Convert sufficient existing catchbasins to inlets to allow present crews to clean the remaining catchbasins twice per year and each inlet once every 2 years.

Which alternative will be more economically attractive over the next 20 years?

Specified Conditions

1. A new mechanical cleaner will cost $30,000, and with a crew it can clean an average of 5,000 catchbasins per year. The useful life of the cleaner is 10 years.
2. The average cost of cleaning a catchbasin is $8.00.
3. The average cost of cleaning an inlet is $3.00.
4. The cost to convert a catchbasin to an inlet is $200.
5. Interest rate = 8%.

Assumptions

1. Sewers are self-cleaning and will not be impacted by the conversion.
2. Neglect inflation costs in the economic analysis.
3. Neglect pollution control aspects.

Solution

1. Compute the existing cleaning capability in dollars.

    5,000 catchbasins x 1 time/yr x $8/catchbasin = $40,000

2. Determine the number of catchbasins that will have to be converted to inlets to meet maintenance objectives with existing crews.

    (a) No. catchbasins x $8 x 2 times/yr + No. inlets x $3 x 0.5 times/yr
        = $40,000

    (b) No. catchbasins + No. inlets = 5,000.

    Solving (a) and (b) simultaneously,

        No. catchbasins = 2,241
        No. inlets = 5,000 - 2,241 = 2,759
        = No. of catchbasins to be converted

3. Compute the capital cost of conversion, and express the amount as annual cost over 20 years.

        Capital cost = 2,759 x $200 = $551,800
        Equivalent annual cost (capital recovery factor - 8% - 20 yr)
        = 0.10185 x $551,800
        = $56,200

4. Compute the present worth of purchasing one mechanical cleaner now and a complete replacement unit 10 years from now, and express the amount as annual cost over 20 years.

        Capital cost = $30,000 + (single payment present worth
        factor - 8% - 10 yr) x $30,000 = $30,000 + (0.4632) x $30,000
        = $43,896

        Equivalent annual cost = 0.10185 x $43,896 = $4,471.

5. Determine the annual cost for alternative (a).

        5,000 x $8 x 2 times/yr + $4,461 (from Step 4) = $84,471

6. Determine the annual cost for alternative (b).

        $40,000 (from Step 2) + $56,200 (from Step 3) = $96,200

Thus, the purchase of a mechanical cleaner would be more economically attractive.

Comment

If inflation were a major consideration, as illustrated in Problem 4, Assumption 9, or if the evaluation period were significantly longer, the cost advantage could very well shift to the structural alternative. The choice, however, is not exclusively economic as is shown in the following example.

EXAMPLE 8: POLLUTION CONTROL AND OTHER COST CONSIDERATIONS

Given that the use of inlets in preference to catchbasins reduces surface maintenance problems and costs, the questions remain as to what extent has the cost merely been transferred to another maintenance area and how has overall pollution control been effected? Compare the annual unit costs of removal of sediment and pollution in terms of BOD_5 for the following:

1. A separate storm sewer system with catchbasins
2. The same system without catchbasins
3. A conventional 10 Mgal/d activated sludge wastewater treatment facility

Specified Conditions

1. Criteria and assumptions of Problems 4 and 5 apply.
2. The activated sludge treatment plant removes 90% of an average influent BOD_5 load of 200 mg/L.

Assumptions

1. The average annual capital and operation and maintenance costs of a 10 Mgal/d activated sludge plant are $950,100 and $283,200, respectively [113].

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2. Within this plant the average annual capital and operation and maintenance costs of the aerated grit chamber alone are $26,480 and $16,425, respectively.
3. The average quantity of grit removed at the plant is 3.5 ft^3 per million gallons of wastewater.

Solution

1. For system No. 1, compute the average annual cost of removing solids from catchbasins.

    [$8.00 x 140 catchbasins x 2 cleanings per year] ÷ 5,141 ft^3 solids removed = $0.44/ft^3

    Assuming a weight of 110 lb/ft^3, this is equivalent to $0.44/ft^3 ÷ 110 lb/ft^3 = $0.004/lb total solids removed.

2. For system No. 1, recompute the average annual cost in terms of BOD$_5$ removed

    [$8.00 x 140 catchbasins x 2 cleanings per year] ÷ [1.04 lb/storm x 50 storms x 140 basins x 0.064 removed (following procedures of Problem 3)] = $4.81/lb BOD$_5$ removed.

3. For system No. 2, compute the additional cost of removing street solids from the storm sewer system assuming 10% by volume settles out in the pipes.

    [$7,614 - $3,449 (annual cost change for 10-yr return period, Step 7, Problem 4)] ÷ 514 ft^3 removed = $8.10/ft^3.

    Assuming a weight of 110 lb/ft^3, this is equivalent to $0.074/lb total solids removed for conditions described in Problem 4 and $0.0074/lb total solids removed for conditions described in Problem 5.

4. For system No. 2, the BOD$_5$ removed is considered negligible.

5. For system No. 3, the average annual cost of removing solids through the aerated grit chamber is

    [$26,480 capital + $16,425 O&M] ÷ [3.5 ft^3/Mgal x 10 Mgal/d x 365 d] = $3.36/ft^3

6. For system No. 3, the average annual cost of removing BOD$_5$ is

    [$950,100 capital + $283,200 O&M] ÷ $\left[200 \text{ mg/L} \times 0.90 \text{ removed} \times 10 \text{ Mgal/d} \times 365 \text{ d} \times 8.34 \frac{\text{lb/Mgal}}{\text{mg/L}} \right]$ = $0.225/lb BOD$_5$ removed.

Comment

In a combined sewer system, trapping and cleaning street solids from catchbasins, if practiced effectively, could significantly reduce peak grit loadings on the treatment plant headworks. This net cost savings, as well as reduced wear in headworks pumps and screens should be considered when evaluating catchbasin effectiveness. It should also be noted that in many combined systems, solids buildup in the pipe system may be largely a dry-weather flow phenomenon, as a result of reduced carrying velocities; thus, observation of the real system behavior is a necessity. For pollution control benefits other than solids, the impact of catchbasins is likely to be small, based on presently available data.

DISCUSSION

The economic evaluations illustrated in this section emphasize the importance of systematic and accurate recordkeeping in catchbasin and inlet maintenance programs and in sewer cleaning. The approach discussed is basically one of how an alternative course of action will prove to be economical in the long run, as

compared to other possible actions. Contributing factors include the time period under consideration, the interest rate, and the anticipated inflationary or noninflationary trends.

The dominant cost factor for decision-makers appears to be sewer cleaning. How will the required cleaning frequency change, and which areas of the pipe network will be subjected to increased deposition as a result of using inlets versus catchbasins? If the differences are small, the use of inlets is favored.

Selected recent developments, a case history example, and suggested continuing program needs are considered in the following section.

SECTION 9

RECENT DEVELOPMENTS AND CONTINUING PROGRAM NEEDS

As has been documented in the previous sections, catchbasins historically have been constructed solely as a reaction device. That is, when solids deposition in sewers was found or suspected to be a problem, catchbasins were installed to trap these solids so that they could be removed at a more convenient location.

Recent thought, however, as now being evaluated through Public Law 92-500, Section 208 Environmental Management Studies, is directed at action rather than reactionary measures. Through the adoption and implementation of best management practices, perhaps we will no longer have to accept as a given condition that gutter flows will be high in inorganic solids, thus closing out the historic role for catchbasins. The purpose of this section is to present briefly and review (1) some recent developments in the design and operation of catchbasins, (2) a case history example, and (3) some thoughts on continuing program needs.

RECENT DEVELOPMENTS

Four aspects of recent developments in the design and operation of catchbasins are described: source controls, shock flow reduction, catchbasin modification, and system controls.

Source Controls

Best management practices are designed to remove or reduce the problem at the source. High solids loadings in gutter flows (catchbasin feed water) are the result of two things: (1) a high available supply of erodible material and (2) suspending and carrying intensities of flow. Remove the supply (through street sweeping, construction site controls, effective ground covers, general good housekeeping, etc.) and reduce the rate of flow (impounding, infiltration-percolation, selective flow routing, check dams, grassed buffer strips, etc.), and you may reduce or eliminate the problem. Because there has been too little demonstration to date on controlled versus uncontrolled broad test areas, the results that can be achieved, unfortunately, remain ill-defined.

Shock Flow Reduction

A system for reducing shock flows on storm drain systems has been developed in Denmark and Norway over the past 15 years [114]. The system basically consists of a storage basin with a rate control orifice on the outlet pipe. Flow enters the basin through the top grating and passes through a sediment trap (optional) into the storage area. When a predetermined level is reached in the basin, discharge begins. The orifice control then regulates the discharge flow to a reduced amount as compared to the inflow.

The sediment trap, located just under the inlet gratings, can be obtained in different materials, depending on the desired size of particle to be trapped. The trap is in the form of a bucket or filter bag, both of which are reusable. The filter bag is capable of retaining solids down to approximately 50 microns. The bucket type is used to trap a much larger size material.

Peak flow reductions to the sewer system (up to 95 percent have been reported) can preclude the need for collection system enlargement, and it is presumed that large quantities of sediment will be retained in the basin or filter. Removal of the sediment presents the same problems and opportunities as with catchbasins.

This system is patented and is undergoing promotional marketing in the United States and Canada at the present time. A demonstration concept proposed for a United States application in Cleveland is shown in Figure 36. By retarding the street runoff inflows to the collection system, preferential capacity is given to roof and building drainage, thus hopefully reducing basement flooding and overflows.

Catchbasin Modification

Existing catchbasins can be modified for one of two major purposes. First, the function of trapping solids can be eliminated by filling the sump of the catchbasin with concrete or some other suitable material. Second, the catchbasin geometry can be altered to effect better solids separation. In addition to these major modifications, the catchbasin can be modified by removing the water seal trap or by making the catchbasin self-draining.

Filling the sump to eliminate the solids separation feature of a catchbasin will allow the solids in the runoff to pass to the sewer. Unless the sewer has adequate velocities to be reasonably self-cleaning or the runoff contains very little sediment, filling the sump should be viewed with caution because this could greatly increase sewer cleaning costs, as has previously been discussed. Designers should evaluate the sewers

catch basin

NEW DETENTION BASIN

HYDRO-BRAKE REGULATOR IN MANHOLE

EXISTING COMBINED SEWER SYSTEM

HYDRO-BRAKE CONCEPT FOR REHABILITATION
OF EXISTING COMBINED SEWER SYSTEMS TO
ELIMINATE OVERFLOWS AND SURCHARGES.
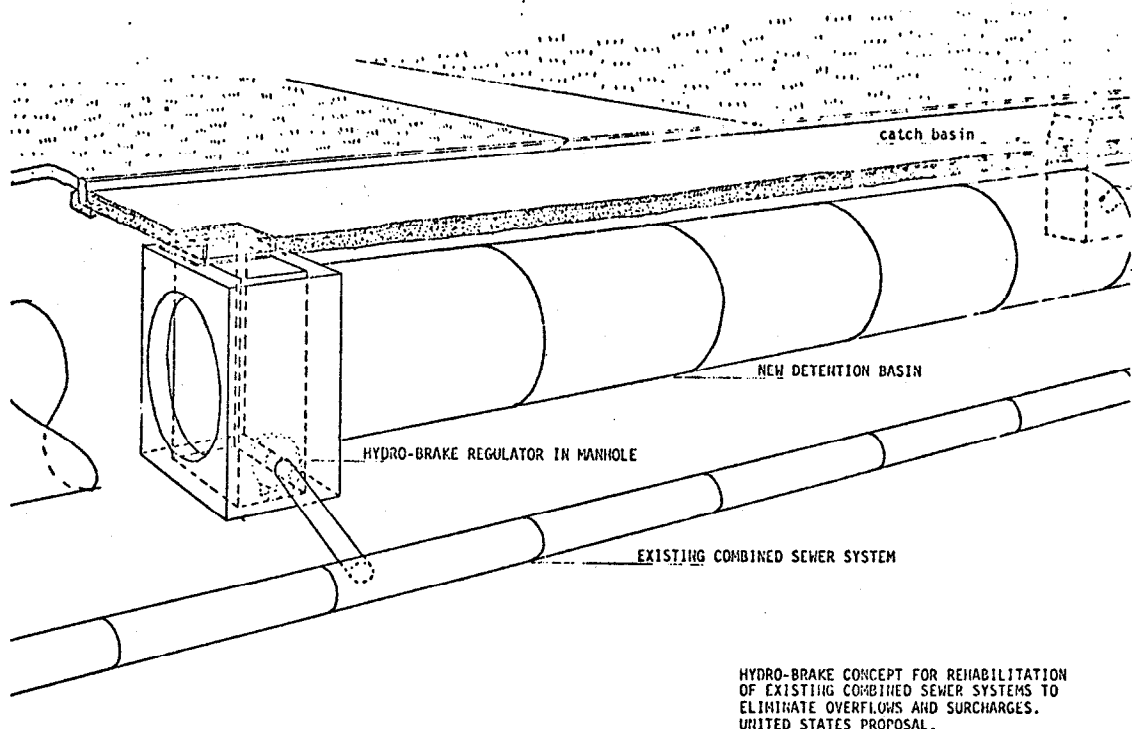UNITED STATES PROPOSAL.

Figure 36. Shock flow reduction concept [114].

to ensure that self-cleaning velocities are maintained before
recommending that catchbasin sumps be filled. A case history of
this approach is outlined later in this section.

Recommendations for optimal catchbasin geometry were presented
earlier. On the basis of the hydraulic model analyses, it is
concluded that supplemental baffling or extensive design
modifications would not be cost effective. The reason is that
present configurations effectively remove coarse solids if there
is proper maintenance, and selective removal of small particle
size and low specific gravity material (which constitutes the
maximum pollutant load) is impractical.

Removing the water seal trap is conditionally recommended on the
basis of the San Francisco catchbasin survey [65] in which it
was found that odor is not necessarily a result of not having a
trap but probably is generated in most cases by septic
conditions in the catchbasin itself. The cleaning program for
catchbasins would be more efficient without the various types of
water seal traps, and the construction costs would be lower.

The increased efficiency of the catchbasin cleaning program might lessen the chances of odor generation by preventing septic conditions from occurring in the catchbasin.

In this same area of reducing septic conditions in the catchbasins, providing a self-draining feature would help to keep the catchbasin contents dry and could lessen the chance of odor generation between cleanings. The problems associated with the construction and maintenance of such a drainage feature, however, appear to outweigh the benefits.

System Controls

Settling basins, flush tanks, and improved solids (swirl) separators are potential system controls to augment or replace catchbasins.

Settling Basins and Flush Tanks--

Conceptually, the objective to be achieved by replacing catchbasins with settling basins is to reduce the cost and to increase the effectiveness of stormwater solids separation techniques. An undergound structure that would be large enough to effectively trap the solids in the stormwater at peak flowrates is envisioned. This basin would also attenuate the storm flow reducing downstream carrying capacity requirements, thus reducing combined sewer overflows in a similar manner to that described under shock flow reduction. After the storm has subsided, the liquid portion would continue to discharge to the sewer and would eventually be treated at a wastewater treatment facility.

In a study conducted by FMC Corporation for the EPA, it was concluded that it was feasible to construct flush tanks in conjunction with keeping combined sewer laterals clear of sediment deposits from dry-weather buildup [104]. The principle in the operation of a flush tank is the release of additional water to the sewer to create a sufficient velocity in the sewer to transport the sedimentary material. The same principle could be used in the controlled cleansing of combined sewer trunklines and storm drains. Either a flush tank or control gate could retard the storm flow until sufficient water was stored to provide the required cleaning velocities, or it could release water from its own supply and perhaps generate flushwaves in sequence to periodically flush the storm drains.

Ideally, the benefits of shock flow reduction and system flushing could be combined if the waters that are temporarily held back contained minimum solids. This introduces a third family of devices--the swirl and helical separators.

Swirl and Helical Separators--

Swirl and helical separators rely on the centrifugal acceleration caused by changing the direction of a stream of water to separate the heavier solids from the overflow water [93, 94, 95, 96, 97, 115, 116, 117, 118, 119]. These devices have been investigated for treating storm flows so that a concentrated stream can be intercepted and sent to the wastewater treatment plant, while the overflow water, which is relatively clean compared to the normal combined sewer overflow, is allowed to continue on to the receiving waters. In the foregoing conceptual application, the overflow stream would be directed to the flush tank to be released only after the downstream collection system drained to near prestorm conditions. Obviously, the complexity of such an approach precludes its being assessed in the form of a general case.

CASE HISTORY

The City of San Francisco, Department of Public Works, has embarked on a phased program to convert catchbasins to inlets in a carefully selected and monitored manner [120]. This program, initiated in 1969, has resulted in the conversion of nearly 1,000 units (out of a total of 25,000) to date, all associated with scheduled street reconstruction and sewer projects. Because the first-phase selection criteria require only scheduled construction for other projects and the nondetection of odors in the affected manholes, the units are located randomly throughout the city.

Evaluation has included matching of odor complaints (recorded with the Bureau of Water Pollution Control between 1967 and 1973) to the location of the units, a preliminary statistical breakdown of the existing inlets with respect to factors contributing to the generation of odors, comments from the Health Department on the effects of public health and rodent control, and comments from the bureau on the maintenance and odor complaints.

Seven of 360 odor complaints over the 6-year study period were in the vicinity of a converted unit. Thus, official complaints in the vicinity of converted units are running at less than half of the citywide rate.

The Health Department comments are particularly enlightening. Eliminating the sumps is endorsed because standing water in catchbasins provides a breeding ground for mosquitos; however, the loss of the water trap creates a situation that may worsen the rat problem [120]:

> The main reason for concern appears to be the practice of [the public] dumping garbage into catchbasins. The curb

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inlets provide a large opening that makes the dumping of
garbage convenient. This opening also allows rats to enter
the catchbasins to use the garbage as a food supply.
Furthermore, without the trap, rats in the sewer system
readily detect and have easy access to the garbage.

The present solution is to restrict the curb inlet openings (see
Figure 34). Based upon its experience to date, the city has
identified the following criteria with respect to proceeding
with the conversion of catchbasins to inlets in the next phase:

1. Does not create a public nuisance by providing a vent
   for odors from the sewer main;

2. Does not contribute to public health problems by
   continuing to be a convenient dump and becoming more
   accessible as a food source for rats;

3. Minimizes the public nuisance and vehicular and
   pedestrian traffic hazard of plugged catchbasins; and,

4. Minimizes the maintenance effort of cleaning
   catchbasins; and, does not transfer the maintenance
   problems to a more difficult situation of cleaning
   culverts and sewer mains.

The city's program is continuing with a contract now being
prepared to convert 250 additional units.

CONTINUING PROGRAM NEEDS

To obtain the data and information required to further evaluate
the function and continued use of catchbasins or other devices,
continuing demonstration programs must be developed and
implemented. Proposed objectives and a discussion of some
recommended studies are presented in the following discussion.

Objectives

The overall objectives of continuing programs should be to
delineate clearly the following:

1. The impact of best management practices in reducing
   solids and other pollutant loads in surface runoff
   that must be collected from urban areas.

2. The effectiveness, through field scale demonstration,
   of closely monitored catchbasin cleaning programs with
   respect to impacts of cleaning frequency and
   techniques on solids carryover, general pollution
   abatement, and associated costs.

3. The problem of solids deposition within real sewer systems and the extent to which this problem is mitigated by properly functioning catchbasins. Is surface runoff introduced through catchbasins or inlets the prime source of the deposit material or merely a contributing source?

4. The cost effectiveness of converting catchbasins to inlets in a major prototype demonstration.

Implementation

Implementation of these programs should be carried out in a minimum of three to five regionally representative urban areas using two similar catchments in each area (one for control and one for demonstration) of, say, not less than 100 nor more than 1,000 acres. Desirable regions would be northeast, midwest, southern, and western because of their differences in climate, hydrology, and system characteristics. The term of the demonstrations would be from 1 to 2 years to cover full seasonal impacts. Ten to 20 percent of the catchbasins in each demonstration site would be monitored weekly on a fixed schedule for sediment accumulation or erosion, trap effectiveness, quality characteristics of the retained flow after mixing, and general observations as to the conditions of the catchment.

In addition, at least two catchbasins in each catchment should be equipped and monitored (quantity and quality) through sequential sampling of the basin influent and effluent during, say, ten storm events.

The results would be compiled, related to hydrology, basin condition, best management practice, cost, etc., and a performance assessment given. Where appropriate, the demonstration would include monitoring of sediment accumulations within the downstream collection system. All maintenance activities in the test catchments would be logged as to labor, equipment, material, and costs, and an assessment as to the transferability of results given.

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Appendix A

GLOSSARY

CATCHBASIN - A chamber or well, usually built at the curb line of a street, for the admission of surface water to a sewer or sub-drain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

COMBINED SEWER - A sewer receiving both surface runoff and sewage.

CURB-OPENING INLET - Vertical opening in the face of a curb for the admission of surface water.

DISSOLVED SOLIDS - The anhydrous residues of the dissolved constituents in water which cannot normally be separated from the water by laboratory filtering.

INLET - A structure that provides an entrance for surface water into a drain which is located below ground. Does not have a sump for trapping solids as in a catchbasin.

INLET GRATE - Framework of bars over an inlet or catchbasin for the admission of surface water.

LATERAL - A sewer which discharges into a branch or other sewer and has no common sewer tributary to it.

SANITARY SEWER - A sewer which normally carries domestic sewage and into which stormwater, surface water, and groundwater are precluded, so far as possible, unless intentionally admitted.

SETTLEABLE SOLIDS - Suspended solids which will subside in quiescent water or other liquid in a reasonable period. Such period is commonly, though arbitrarily, taken as one hour.

SEWER - A pipe or conduit generally closed, but normally not flowing full, for carrying sewage and other waste liquids.

STORM SEWER - A sewer which carries stormwater and surface water, street wash and other wash water, or drainage, but excludes sewage and industrial wastes.

SUSPENDED SOLIDS - Solids that either float on the surface of, or are in suspension in, water or other liquids, and which are largely removable by laboratory filtering.

TOTAL SOLIDS - The dissolved and undissolved mineral constituents in water.

Appendix B

ANALYSIS OF CATCHBASIN SURVEY DATA

The principal objective pursued in the analysis of experimental
or survey data is comprehension of its significance. Typically,
the approach followed when analyzing data related to a given
variable is to define this central tendency and dispersion. The
measures used most commonly for this purpose are the arithmetic
mean and the standard deviation. In general, these measures are
adequate so long as the data are more or less evenly distributed
above and below the mean. Unfortunately, this is often not the
case with certain types of experimental and survey data.

As an example, data dealing with catchbasins tend to be unevenly
distributed or skewed. The reason for this is that the more
extreme values tend to deviate beyond the mean to a greater
extent than do the values that are less than the mean. This can
be seen clearly in the sample data reported in Table B-1. Often,
when sample data are skewed, they can be analyzed using skewed-
probability paper or log-probability paper. For the data con-
sidered in this report, it was found that a geometric distribu-
tion was best. For a geometric distribution the mean, M_g , and
the standard deviation, σ_g , are computed using the following
expressions:

$$\log M_g = (\Sigma \log x)/n$$
$$\log \sigma_g = \sqrt{(\Sigma \log^2 x_g)/(n-1)}$$
$$\log x_g = \log x - \log M_g$$

TABLE B-1. SUMMARY DATA ON AREA PER CATCHBASIN FOR CITIES IN THE UNITED STATES [102]

City	Incorporated city area, mi^2	Number of catchbasins	Area per catchbasin, acre
1	36.7	32,000	0.7
2	18.9	1,100	1.2
3	18.4	10,090	1.2
4	45.4	25,000	1.2
5	13.3	5,500	1.5
6	29.9	12,000	1.6
7	34.3	8,350	2.6
8	60.3	14,546	2.7
9	22.4	3,561	4.0
10	50.2	6,000	5.4
11	29.4	3,500	5.4
12	26.1	2,500	6.7
13	83.9	5,100	10.5
14	19.0	1,100	11.1
15	41.8	2.069	12.9
16	95.2	4,000	15.2
17	316.9	10,500	19.3
18	131.5	2,000	42.0

mi^2 = 2.59 km^2
acre = 0.4047 ha

Appendix C

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CONVERSION FACTORS
U.S. Customary to SI Metric

U.S. customary	Abbr.	Multiplier	Symbol	SI metric unit
acre	acre	0.405	ha	hectare
acre-foot	acre-ft	1,233.5	m^3	cubic metre
cubic foot	ft^3	28.32	L	litre
cubic feet per minute	cfm	0.0283	m^3/min	cubic metres per minute
cubic feet per second	cfs	28.32	L/s	litres per second
cubic inch	$in.^3$	16.39	cm^3	cubic centimetre
		0.0164	L	litre
cubic yard	yd^3	0.765	m^3	cubic metre
		764.6	L	litre
degree Fahrenheit	°F	0.555 (°F-32)	°C	degree Celsius
feet per minute	ft/min	0.00508	m/s	metres per second
feet per second	ft/s	0.305	m/s	metres per second
foot (feet)	ft	0.305	m	metre(s)
gallon(s)	gal	3.785	L	litre(s)
gallons per acre per day	gal/acre·d	9.353	L/ha·d	litres per hectare per day
gallons per capita per day	gal/capita·d	3.785	L/capita·d	litres per capita per day
gallons per day	gal/d	4.381×10^{-5}	L/s	litres per second
gallons per square foot per day	$gal/ft^2 \cdot d$	1.698×10^{-3}	$m^3/m^2 \cdot h$	cubic metres per square metre per hour
		0.283	$m^3/ha \cdot min$	cubic metres per hectare per minute
gallons per minute	gal/min	0.0631	L/s	litres per second
gallons per square foot per minute	$gal/ft^2 \cdot min$	2.445	$m^3/m^2 \cdot h$	cubic metres per square metre per hour
		0.679	$L/m^2 \cdot s$	litres per square metre per second
gallons per square foot	gal/ft^2	40.743	L/m^2	litres per square metre
horsepower	hp	0.746	kW	kilowatts
inch(es)	in.	2.54	cm	centimetre
inches per hour	in./h	2.54	cm/h	centimetres per hour
million gallons	Mgal	3.785	ML	megalitres (litres x 10^6)
		3,785.0	m^3	cubic metres
million gallons per acre per day	Mgal/acre·d	0.039	$m^3/m^2 \cdot h$	cubic metres per square metre per hour
million gallons per day	Mgal/d	43.808	L/s	litres per second
		0.0438	m^3/s	cubic metres per second
mile	mile	1.609	km	kilometre
parts per billion	ppb	0.001	mg/L	milligrams per litre
parts per million	ppm	1.0	mg/L	milligrams per litre
pound(s)	lb	0.454	kg	kilogram
		453.6	g	grams
pounds per acre per day	lb/acre·d	0.112	$g/m^3 \cdot d$	grams per square metre per day
pounds per day per acre	lb/d·acre	1.121	kg/ha·d	kilograms per hectare per day
pounds per 1,000 cubic feet	$lb/1,000\ ft^3$	16.077	g/m^3	grams per cubic metre
pounds per million gallons	lb/Mgal	0.120	mg/L	milligrams per litre
pounds per cubic foot	lb/ft^3	16.02	kg/m^3	kilograms per cubic metre
pounds per square foot	lb/ft^2	4.882×10^{-4}	kg/cm^2	kilograms per square centimetre
pounds per square inch	$lb/in.^2$	0.0703	kg/cm^2	kilograms per square centimetre
square foot	ft^2	0.0929	m^2	square metre
square inch	$in.^2$	6.452	cm^2	square centimetre
square mile	mi^2	2.590	km^2	square kilometre
square yard	yd^2	0.836	m^2	square metre
standard cubic feet per minute	$std\ ft^3/min$	1.699	m^3/h	cubic metres per hour
ton (short)	ton	0.907	Mg (or t)	megagram (metric tonne)
yard	yd	0.914	m	metre